Optimising Fuel Supply Chain for Fleet Operations in Large Organisation

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***Abstract*— Performance in the supply chain operations regarding the management of fleet operations and its fuel consumption have been one of the most critical concerns of large private and government organizations. Organisations are adapting more efficient, environmental friendly and safer fuel and fleet management systems considering the high cost of fuel and the associated impacts on environment. This Paper reviews and analyses the fuel supply chain using Monte Carlo Simulation to optimise the fuel supply chain and evaluate the feasibility of future development alternatives in fleet operations for large organisation. Considering the case of a local government organisation in Australia, this paper illustrates important issues, considerations in cost and risk management of fuel supply operations.**

Keywords— ***Fuel Supply Chain, Cost and Risk Management Monte Carlo Simulation.***

I. INTRODUCTION

Large public organisation supply chain capabilities have special scale, complexity and characteristics that are manifested with the different purposes and roles which these organizations execute (natural disaster response, infrastructure improvement, waste management, and regular operations to serve the citizens). Public organisation supply chains face significant challenges due to a broad combination of stakeholders and participants with different businesses, processes and systems; high levels of investments; higher standards and regulations; political barriers and inadequate infrastructure. These challenges are intensified with the steady-state nature of government legislation, the different risks that organisations face and also the rapidly escalating cost of fuel which sustains most of the supply chains now a days.

Public and private organisations are adapting more efficient, ecological and safer fuel management systems considering the high cost of fuel and the associated impacts on the environment. For instance, the number of fuel management systems in active use is forecasted to grow at a compound annual growth rate of 21.7 percent from 1.5 million units at the end of 2009 to 4.0 million by 2014 (Berg Insight, 2010). Given the existing circumstances of fuel prices, organisations are under increased pressure to employ technological solutions to manage their mobile assets and their associated fuel consumption more competently (Delehaye et al., 2007). An improved fuel [1]management system can be used to maintain, control and monitor fuel consumption and stock. This enhanced control provides the base to take measures towards a more efficient use of the fuel needed to run an organisation's fleet. An effective fuel supply management system also can support decisions to fleet improvement initiatives that can result in reductions of operating cost and enhanced organisational productivity.

This paper responds to the necessity of improving the control over the costs and management of the fleet operations associated to fuel supply. From this perspective, the project motivation is the analysis and evaluation of more capable alternatives which provide the way to advance in the fuel supply practices and techniques in order to increase the overall performance of the system under the correct compliance of environmental and health & safety regulations.

For the purpose of this study, a local government organisation in Australia has been chosen to improve its fuel supply chain and to develop their fuel supply management operations. This Project is aimed to review their existing processes and evaluate the feasibility for future development alternatives. This study analyses the organisation's current consumption of fuel, the evaluation of new alternatives that helps increase the efficiency of its fuel supply procedures using Monte Carlo Simulation approach. This paper proposes the most efficient and cost effective method or combination of methods to supply the fuel consumption for the organisation's fleet (passenger vehicles, light commercial vehicles, heavy transport, major heavy equipment, specialist transport, and general plant equipment).

II. LITERATURE REVIEW

A. Fuel Supply chain

Collier & Evans (2008) defined supply chain as the proportion of the value chain that focuses primarily on the physical movement of goods and materials, and supporting flows of information and financial transactions through the supply, production and distribution processes. It is the integration of information, physical material and product flow, financial activities to increase sales/service and reduce cost, increased cash flow. Value chain integration can be defined as the process of managing information, physical goods and services to ensure their availability at the right place, at the

right time, at the right cost, at the right quantity, and with the highest attention to quality. Success of the entire value chain depends on the design and management of all aspects, including, suppliers, inputs, processes, outputs, etc. For this reason, management must determine how to maximise value by designing enhanced processes and systems that reduce cost or price and increase perceived benefits. Most of the published literatures on supply chain concentrate on supply chain risks, triggered by a recent series of catastrophic events that have impacted the global economies and supply chains. The existing studies that are found in the literature have been instrumental in identifying and analysing several causes of disruptions and risks in supply chains and most of them are based on case studies and empirical evidence (Giannakis and Louis, 2010). Wagner and Bode (2006) conducted a large-scale investigation on important relationship between supply chain vulnerability and supply chain risk, and provides a finer understanding of the antecedents of supply chain vulnerability. Melnyk et al. (2009) provide an innovative formalized methodology in mitigating disruptions in supply chains with the use of discrete event simulation.

This project considered logistics principles and theories in order to create value and make more effective fuel supply system of organisations, and to improve the links between facilities and processes within different areas of the organisation. Fuel operations of organisations are seen as a value chain or network of facilities and processes. The Organisation's fuel supply chain includes suppliers of fuel, different internal processes between refuelling facilities, labour, capital and information resources, and outcomes that principally consist in supply of fuel to the organisation's internal users (Figure 1).

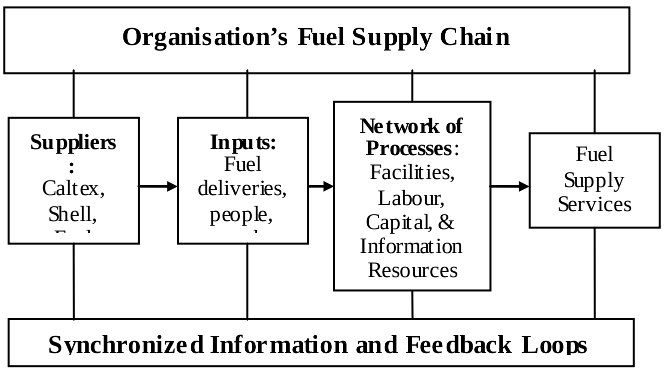


Fig.1. Organisation fuel supply chain

To achieve the objective of this research, this project aims to analyse demand and cost of fuel in Organisation's all different fuel supply methods, cost of labour involved with internal fuel operations and quality of the system (service quality, environmental quality, and safety), in order to try to coordinate and manage information, physical goods, and services among the users in the organisation's fuel value chain.

B. Fuel Global and Australian Condition

Understandings of the current situation of fuel provide an important rationale for this project. The cost and price of oil is rising continuously, especially from 2001. Figure 2 illustrates the fuel price evolution from 1986 to 2008 (World Economic Forum, 2009). Following this trend, it is understandable how many businesses and logistic operators that rely on fuel have been seriously impacted with current trends on fuel prices.

The price of fuel in Australia is mainly influenced by three broad components: International benchmark prices, taxes, and other costs and margins (Australian Competition & Consumer Commission, 2010). International prices are strongly influenced by the Organization of the Petroleum Exporting Countries (OPEC), which is conformed by the countries with high oil reserves (Algeria, Angola, Ecuador, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, the United Arab Emirates, and Venezuela) (Gürcan Gülen, S. 1996).

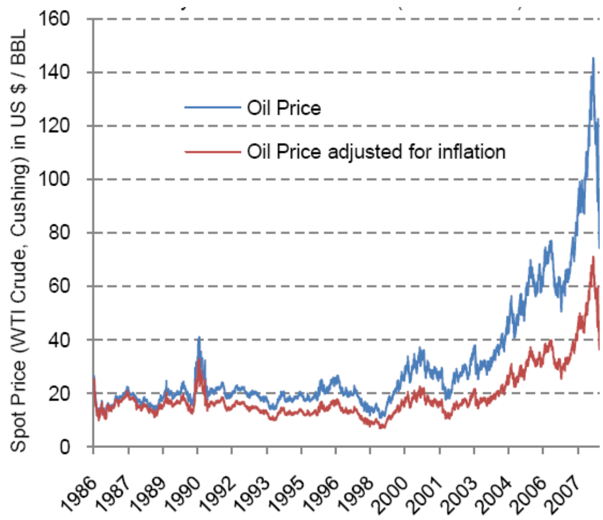


Fig.2. Fuel price evolution from 1986 to 2008 (world economic forum, 2009)

C. Safety in Fuel Facilities

Safety recommendations provided by safety and hazardous materials handbook authors, review philosophies and principles that can be applied to protect the organisation's refuelling facilities. Nolan (1996) stated that to protect the upgrades of refuelling facilities the same philosophy that would apply to any building or installation should be followed. Some requirements such as personnel evacuation, containment, isolation, and suppression should be taken into consideration.

Other important standards in the area of safety building or upgrading refuelling facilities are: AS 1692—2006 (Steel tanks for flammable and combustible liquids) and AS 1657—1992 (Fixed platforms, walkways, stairways and ladders — Design, construction and installation). However in Australia, the Australian Standard AS 1940 (The storage and handling of flammable and combustible liquids) is the most important regulation for the design of fuel storage systems. This Standard ensures that tanks and auxiliary equipment are correctly maintained and appropriate fuel handling procedures are met. This standard also includes matters relating to facility operations and the management of emergencies.

III. CASE STUDIES: FUEL SUPPLY CHAIN FOR FLEET OPERATIONS IN LC COUNCIL

A case study has been conducted for the purpose of understanding and analysis of objective and achievement of this research. For confidentiality purpose we are restricted to expose the organizations identity here but we use an imaginary name to represent our organization in the rest of the paper that is LC Council. This local government organization is one of largest city council in Australia. The total area of the council is approximately 1000 sq km and comprises of four main streams that respond the needs of 277,000 residents: Organisational services, Infrastructure services, Community & customer services, and Strategy and Outcomes.

LC Council's Fuel Operation

The Council, as other organizations use a variety of methods to supply the fuel necessary for its fleet fuel demand. The flow within the Council's fuel supply chain starts from the major companies of crude oil and the big distributors of fuel in Australia (Shell and Caltex). The Council purchases bulk fuel to operate their in-house fuelling facilities, uses fuel cards (mainly from Caltex) and outsource a fuel refilling service through fuel mobile tankers operators (Freedom Fuels Pty Ltd, Diesel Express and Mini Tankers) (Figure 3).

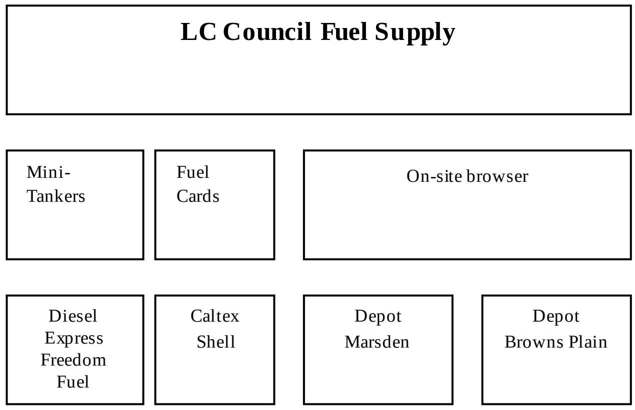


Fig.3. LC Council fuel supply system

Internal information about fuel supply for Council was obtained and analysed during the initial research phase of the project. The information was gathered from interviews with the involved stakeholders of the fuel management operations and reports of fuel consumption.

A network modelling analysis was carried out first to develop different alternatives in the supply chain. This analysis was intended to review all the possible changes in the flow of fuel that help to determine all potential combinations of supply methods and their associated costs (Figure 4)

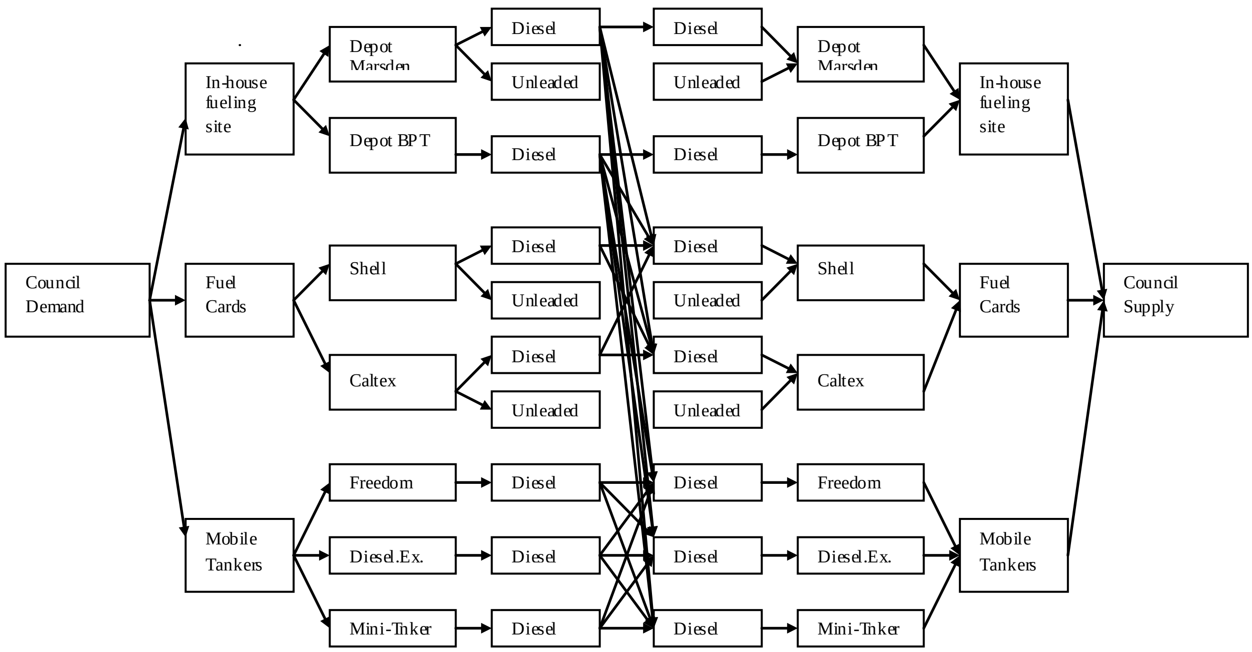


Fig.4. Fuel Supply network analysis

A. Deterministic Approach

A preliminary deterministic analysis has been conducted in an excel spread-sheet to achieve a rough estimation of the cost of each alternative ignoring any random variations and used point estimations. The annual fuel cost estimations for each alternative were made by taking into account the average demand and price of each supply method in the same period of analysis (September 2009 to August 2010). Please see Table 1.

TABLE 1
DETERMINISTISTIC ANALYSIS

	Deterministic Analysis		
	Price AUD	***Annual Demand lit***	***Annual Costs AUD***
Total Mobile tankers	1.50	330919	494723.905
Moble tankers Freedom fuels	1.52	285132	431974.98
Moble tankersDidel express	1.37	45787	62819.764
Total Mobile Cards	1.23	829419	1021014.789
Total Shell fuel cards	1.27	47280	60187.44
Shell fuel cards Diesel	1.24	24652	30593.132
Shell fuel cards Unleaded	1.30	22629	29440.329
Total Caltex fuel cards	1.23	782139	960466.692
Caltex fuel cards Diesel	1.24	346153	429922.026
Caltex fuel cards Unleadedl	1.23	427651	526010.73
Caltex fuel cards LPG	0.59	8334	4942.062
Total Depot Marsden	1.18	514752	604833.6
Diesel	1.18	451854	531832.158
Unleaded	1.16	62898	73150.374
Total Brown Plains Depot Diesel	1.20	107165	128598
Total Diesel	1.28	1,260743	1,616,272.526
Total Unleaded	1.23	513,177	628,641.825
Total Council	**1.26**	**1,773,920**	**2,238,687.04**

The initial input of the deterministic analysis includes current average price, demand (litres) and total fuel cost per year for each fuel supply category. The associated cost of the different alternatives was calculated keeping static the demands of each category and changing only the prices if these demands were transferred to another supply methodology. The following assumptions (Table 2) also were considered into the model to estimate operational costs. These assumptions were reviewed and evaluated for subject matter experts inside the Council to guarantee the reliability and consistency of the results.

TABLE 2
ASSUMPTION FOR OPERATIONAL COSTS

Assumption	Costs in AUD
Transfer Browns Plain Depot to Depot Marsden	15,000
Tank decommissions	8,303
Mini tanker's fuel price (new)	1.33
Fuel price with own mobile tanker	1.5
Annual inventory costs Depot M	17,720
Annual inventory costs Depot BP	4,330
Annual costs to operate own mobile tanker	119,600
Annual costs to operate hired mobile tanker	60,000

After all the associated costs of the alternatives were determined, the results were summarized and are displayed in Table 3. Compared with the existing Council's cost, red values represent annual cost overruns and blacks represent annual cost savings. These savings are presented in values and percentages. Only 6 out of 29 alternatives offer fuel cost savings. The major possible savings comes from transferring the demand of Freedom Fuels mobile tankers operator to a more low-priced supplier (Diesel Express or Mini Tankers). This alternative is currently implemented by the Council and expected to achieve savings up to $50,000 per year. Other savings can be achieved shifting the unleaded demand of Shell unleaded fuel cards to Caltex fuel cards. However, due to the low demand of Shell fuel cards, this alternative will generate only $1,748 of savings per year (alternative 7c in Table 3).

TABLE 3
POSSIBLE COST OVERRUNS OF THE ALTERNATIVES

Alter-native	Description	Cost of fuel $	Cost over-un(red) /Cost saving $	% Cost overrun(red)/Cost saving
1a	Supply the current Marsden demand (Diesel and Unleaded) through Caltex fuel cards	2282656	33,390	1.5
1b	Supply only the current Diesel demand of Marsden from Caltexfuel cards	2278461	29195	1.3
1c	Supply only the current Unleaded demand of Marsden from Caltexfuel cards	2253461	4195	0.2
2a	Supply the current Marsden demand (Diesel and Unleaded) through fuel cards and decommissioning both two underground tanks at Marsden	2282656	33390	1.5
2b	Supply only the current Diesel demand of Marsden from Caltexfuel cards and decommissioning only Diesel underground tanks at Marsden	2278461	29195	1.3
2c	Supply only the current Diesel demand of Marsden from Caltexfuel cards and decommissioning only Unleaded underground tanks at Marsden	2253461	4195	0.2
3a	Supply the current Marsden Diesel demand through the mini mobile tanker suppliers	2319245	69979	3.7
3b	Supply the current Marsden Diesel demand through the Freedom mobile tanker suppliers	2401787	152521	6.8
3c	Supply the current Marsden Diesel demand through the Diesel express mobile tanker suppliers	2337392	88126	3.9
4a	Supply the current Unleaded demand of Marsden from Caltexfuel cards and Supply the current Marsden Diesel demand through the mini mobile tanker suppliers	2323440	74174	3.3
4b	Supply the current Unleaded demand of Marsden from Caltexfuel cards and Supply the current Marsden Diesel demand through the Freedom mobile tanker	2405982	156716	7.0
4c	Supply the current Unleaded demand of Marsden from Caltexfuel cards and Supply the current Marsden Diesel demand through the Diesel express	2341587	92321	4.1
5a	Shift the current Freedom fuel supply to Minitankers	2197180	-52086	-2.3
sb	Shift the current Freedom fuel supply to Diesel express	2208631	-40635	-1.8
5c	Shift the current Diesel express supply to Minitankers	2247427	-1839	-.1
5d	Shift the current Diesel express supply to Freedom fuel	2255791	6525	.3
6a	Supply the current Browns plain diesel demand through the Mini mobile tanker suppliers	2263474	24228	.6
6b	Supply the current Browns plain diesel demand through the Freedom mobile tanker suppliers r	2283050	33784	1.5
6c	Supply the current Browns plain diesel demand through the Diesel express mobile tanke	2267778	18512	.8
7a	Shift the Shell fuel cards demand to Caltex fuel cards (Diesel and Unleaded)	2247539	-1727	-0.1
7b	Shift the Shell fuel cards demand to Caltex fuel cards (Diesel)	2249287	21	0.0
7c	Shift the Shell fuel cards demand to Caltex fuel cards (Unleaded)	2247518	-1748	-0.1
8	Supply the current Browns plain diesel demand through the Mini mobile tanker suppliers and Supply the current Marsden demand (Diesel and Unleaded) through Caltex fuel cards	2296864	47598	2.1
9	Supply the current Browns plain diesel demand through the Mini mobile tanker suppliers and transfer above ground tank from Browns plain to Marsden Depot	2263474	14208	0.6
10	Supply the current Browns plain diesel demand through the Mini mobile tanker suppliers and Supply the current Unleaded demand of Marsden from Caltexfuel cards, and Supply the current Marsden Diesel demand through the mini mobile tanker suppliers	2337684	88382	3.9
11	Supply the current Browns plain diesel demand through the Mini mobile tanker suppliers and Supply the current Marsden demand (Diesel and Unleaded) through Caltex fuel cards and transfer above ground tank from Browns plain to Marsden Depot and decommissioning both two underground tanks at Marsden	2296864	47598	2.1
12	Supply the current Browns plain diesel demand through the Mini mobile tanker suppliers and transfer above ground tank from Browns plain to Marsden Depot, supply the Marsden demand using the above ground tank, Supply the current Unleaded demand of Marsden from Caltex fuel cards, and decommissioning both two underground tanks at Marsden	2267669	18403	0.8
13	Operate an own mobile tanker to supply current demands of fuel	2250903	1637	0.1
14	Hire and operate mobile takers 2250903 1637	2250903	1637	0.1
15	Shift the current all fuels mobile tanker operation demand to Minitankers and move Shell fuel cards demand to Caltex	2193593	-55673	-2.5

B. *Stochastic Analysis*

Problem with the deterministic approach is that it only shows one potential scenario because inputs are fixed (only one value is given to each cell). However, in reality, internal and external circumstances that affect the performance of organisations are characterized by uncertainty and variability. For this reason, to realistically estimate variables in this analysis, variations need to be taken into consideration and uncertainties need to be quantified. This implies that the fuel supply chain problems also need be analysed stochastically to determine the optimum amount of fuel in the different supply methods that the Council operates by capturing the uncertainties and variations in the fuel prices and Council's demands for fuels. The objective is to minimise the total cost which includes the cost of fuel and administrative and inventory holding cost at various points. The analysis is carried out using Oracle Crystal Ball which is spreadsheet-based application software that uses Monte Carlo Simulation for predictive modelling, forecasting, simulation and optimisation.

The model takes into account the deterministic estimations of demand in litres and price for each fuel supply category as a base. Having this base case scenario, a probability of occurrence (for both demand and price) was

estimated following the historic values since January 2009. The definition of each probabilistic distribution was calculated using Crystal Ball batch fit tool. This tool helps to define assumptions and calculate correlations when historical data is available for variables. Batch fit tool automatically selects the best fitting probability distribution for each historic data series and provide the parameters to use in a model. In this case, the previous collected historic information for each fuel supply category is taken to determine the probability of occurrence, which follows the historic behaviour that demand and price have had in the previous 20 months.

The shaded cells in Table 4 represent the variables (assumptions) of the model that represent probabilistic distributions which describe potential variations. Figure 5 shows price distribution of one of the variables (price of Freedom Fuels) using 20 month's price data.

TABLE 4
SIMULATION MODEL – BASE CASE SCENERIO

	Deterministic Analysis			Simulation		
	Price $	***Annual Deamnd lit***	***Annual Costs $***	***Price $***	***Annual Deamnd lit***	***Annual Costs $***
Total Mobile tankers	1.5	330919	494723		330919	494723
Moble tankers Freedom fuels	1.52	285132	431974	1.52	285132	431974
Moble tankersDidel express	1.37	45787	62819	1.37	45787	62819
Total Mobile Cards	1.23	829419	1021014		829419	1021014
Total Shell fuel cards	1.27	47280	60187		47280	60187
Shell fuel cards Diesel	1.24	24652	30593	1.24	24652	30593
Shell fuel cards Unleaded	1.3	22629	29440	1.3	22629	29440
Total Caltex fuel cards	1.23	782139	960466		782139	960466
Caltex fuel cards Diesel	1.24	346153	429922	1.24	346153	429922
Caltex fuel cards Unleadedl	1.23	427651	526010	1.23	427651	526010
Caltex fuel cards LPG	0.59	8334	4942	0.59	8334	4942
Total Depot M	1.18	514752	604833		514752	604833
Diesel	1.18	451854	531832	1.18	451854	531832
Unleaded	1.16	62898	73150	1.16	62898	73150
Total BP Depot	1.2	107165	128598	1.2	107165	128598
Total Diesel	1.28	1,260,743	1616272		1,260,743	1616272
Total Unleaded	1.23	513,177	628641		513,177	628641
Total Council	**1.26**	**1,773,920**	**2238687**		**1,773,920**	**2238687**

To simulate the behaviour of the variables, Crystal Ball generates each trial random values using the predetermined probabilistic distributions. Each trial describes a possible scenario with the pre-assigned probabilities. After many runs, Crystal Ball generates the results of the selected outputs and provides different types of analysis. The presented simulation ran 5000 scenarios computing different values for these 20 predetermined assumptions (price and demand of each fuel supply category). The simulation was intended to determine the range and distribution of the most important outcome for this analysis which is cost of fuel.

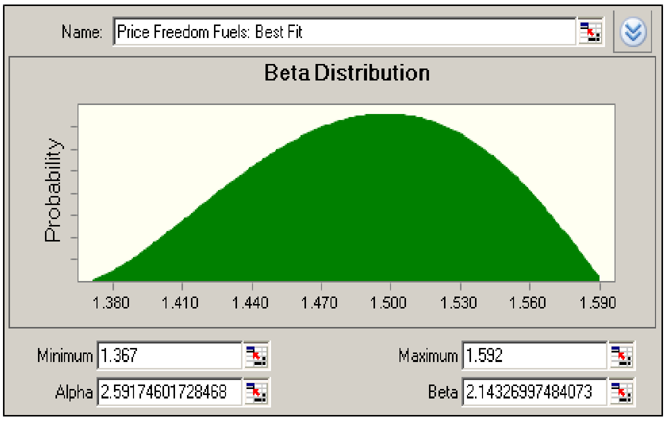


Fig.5. Example – Price variations of Freedom fuel

IV. RESULTS AND DISCUSSIONS

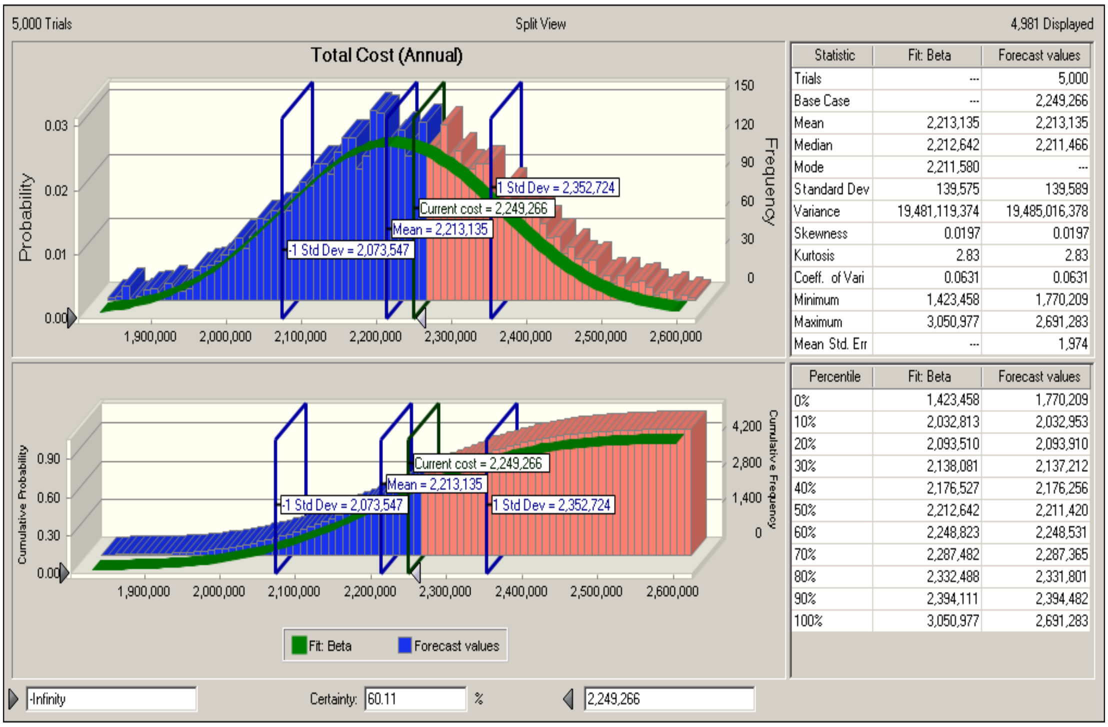
A. Analysis of the Outcomes

The most common and easy approach to understand the results of a Monte Carlo simulation is through a frequency chart or histogram.

These charts provide an insight of the distribution of the preselected forecasted outcomes. In other words, with these charts it is possible to predict the behaviour of variables that the model needs to evaluate. Using Crystal Ball histogram charts allow the calculation of certainty levels which shows the probability of achieving results within a specific range. Figure 6 illustrates the forecasted histogram of Council's total annual fuel cost considering the variations in price and demand for each fuel supply category observed in previous 20 months. Here, Beta is the best fitting distribution for the annual total cost of fuel with parameters: minimum=1,423,458, maximum=3,050,977, alpha=15.99342 and beta=16.96891. After 5000 iterations, Council's annual total fuel cost, total unleaded fuel and total diesel fuel were estimated. It can be established that while unleaded cost distribution is more peaked and condensed (low standard deviation=54,580), diesel is more widely spread ranging from around $1,200,000 to $1,800,000 per year (higher standard deviation= 116,414).

Crystal Ball histogram charts allow the calculation of certainty levels which shows the probability of achieving results within a specific range. Figure 6 exhibits that with a certainty of 60.11% (blue colour portion), the expected total cost are remain bellow the current annual cost ($2,238,687).

The same matrix of alternatives that were described in the deterministic analysis has been used to evaluate the stochastic cost performances of all predefined alternatives.



Statistic	Fit: Beta	Forecast values
Trials	---	5,000
Base Case	---	2,249,266
Mean	2,213,135	2,213,135
Median	2,212,642	2,211,466
Mode	2,211,580	---
Standard Dev	139,575	139,589
Variance	19,481,119,374	19,485,016,378
Skewness	0.0197	0.0197
Kurtosis	2.83	2.83
Coeff. of Vari	0.0631	0.0631
Minimum	1,423,458	1,770,209
Maximum	3,050,977	2,691,283
Mean Std. Err	---	1,974

Percentile	Fit: Beta	Forecast values
0%	1,423,458	1,770,209
10%	2,032,813	2,032,953
20%	2,093,510	2,093,910
30%	2,138,081	2,137,212
40%	2,176,527	2,176,256
50%	2,212,642	2,211,420
60%	2,248,823	2,248,531
70%	2,287,482	2,287,365
80%	2,332,488	2,331,801
90%	2,394,111	2,394,482
100%	3,050,977	2,691,283

Fig.6. Forecasted histogram of annual total fuel costs

In order to evaluate the different 29 alternatives that were determined during the initial stage of the study, a trend chart analysis was used to review how the impact of historic variability in prices and demand of fuel influence the variability in cost when a specific alternative is executed. The main objective of a trend chart is to summarize graphically the information from multiple alternatives, making easy to discover differences between related forecasts.

Figure 7 represent the trend chart analysis for all different alternatives. The x-axis displays on the base case scenario and all different alternatives.

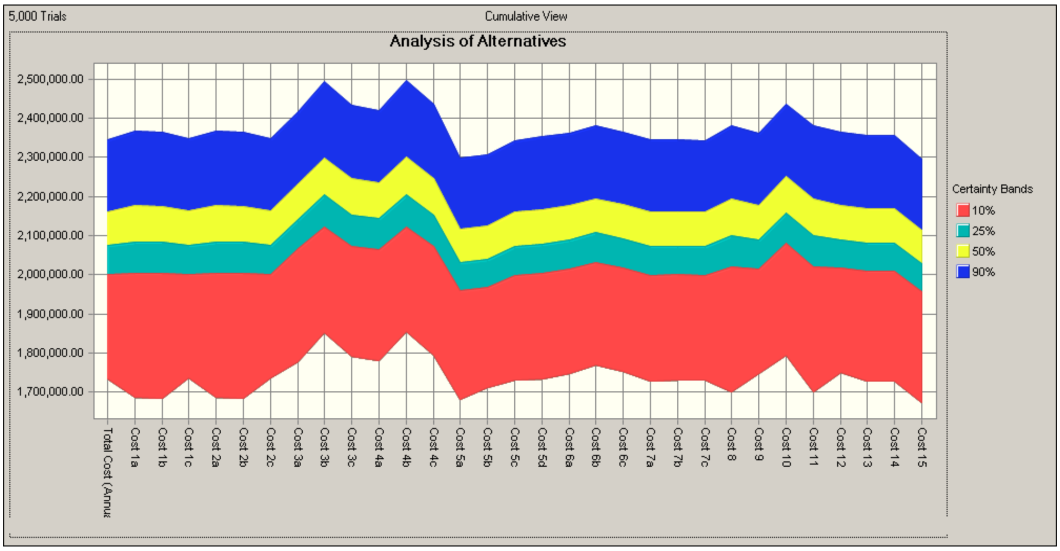


Fig.7. Trend chart (alternative) cumulative view

The y-axis defines the certainty ranges of values that the total cost can take for each alternative considering the previously described historic assumptions of price and demand from each supply category within the Council. The figure displays certainty ranges in a series of coloured bands. This graphical representation provides a comparison of the cost of the alternatives considering the variability of Council's prices and demand of fuel during the last 20 months. The chart, it implies that alternative 3b and 4b have the highest costs and 5a, 5b and 15 have the lowest. Even though, the majority of alternatives do not create cost savings, there are other decisive factors that should be considered in order to improve the Council's fuel supply operation such as decommissioning the existing underground tanks at Marsden depot. EPA underground storage regulation suggests exploring and evaluating an operational substitute that minimises the environmental risk since the age of these tanks (Marsden diesel tank installed before 1981, unleaded tanks were installed in the late 80's)

B. Title Selecting the best alternative

The weighted score method also called preference matrix or factor-rating method is used to compare different alternatives which have multiple evaluation criteria. For this technique is required to allocate scores for the factors according their significance. In other words evaluators assign weights for each factor trying to represent how important is this factor in the final decision. The total score for each alternative is the sum of weighted scores.

Using the cost analysis and simulation results, evaluation of the alternatives were performed in selecting the best the alternatives methods. Analysing the costs, operational impacts, viability of the options, expected level of efficiency, safety & health, and other environmental considerations, only 5 alternatives were preselected to be evaluated with additional criteria in a second round of assessment (Table 5).

These alternatives consider crucial decisions such as: Use Caltex fuel cards to supply the current Marsden on site bowsers demand, Use Mini tankers to supply Browns Plains Tip, Decommission Underground Tanks at Marsden, and transfer the above ground tank from Browns Plains Tip to Marsden Depot.

Using a Kepner Tregoe matrix, these 5 alternatives were assessed with different criteria such as cost, ease of implementation, implementation time, impact, benefit/cost relationship, health & safety compliance, cultural impact, resistance to change, uncertainty about effectiveness, and environmental compliance. Kepner Tregoe decision making is a structured methodology, to prioritize and evaluate alternatives in order to find the best unbiased decision that minimizes risks and negative consequences.

To define the assessment criteria used in this analysis, objectives were classified in three different categories: strategic requirements (must have), operational objectives (want to have), and restraints (limits in the system). Cost, ease of implementation, and implementation time, were classified as operational objectives. Impact of the alternative, benefit / cost relationship and health & safety compliance, were classified as strategic requirements. Finally, cultural impact, resistance to change, uncertainty of effectiveness, and environmental performance were classified as Restraints. Criteria were first ranked assigning relative weights to them. Weighted scores were calculated multiplying the relative scores of the alternative's performance by the weight of each objective. Alternative numbers 12 and 15 were evaluated as the most beneficial for the Council (with weighted scores 241 and 278 respectively). The alternative 15 was assessed high in all criteria and includes the recently implemented transition for a more cost-efficient supplier for Mobile refuelling services (Mini Tankers). An important advantage that resulted clear from the analysis was the relocation of the above tank from Browns Plains Tip to Marsden Depot.

TABLE 5

BEST FIVE ALTERNATIVES

Alternative	Description	Cost of fuel $	Cost overrun(red) /Cost saving $	% Cost overrun (red)/Cost saving
2a	Supply the current Marsden demand (Diesel and Unleaded) through Caltex fuel cards and decommissioning both two underground tanks at Marsden	2282656	33390	1.5
8	Supply the current Browns plain diesel demand through the Mini mobile tanker suppliers and Supply the current Marsden demand (Diesel and Unleaded) through Caltex fuel cards	2296864	47598	2.1
10	Supply the current Browns plain diesel demand through the Mini mobile tanker suppliers and Supply the current Unleaded demand of Marsden from Caltexfuel cards, and Supply the current Marsden Diesel demand through the mini mobile tanker suppliers	2337684	88382	3.9
12	Supply the current Browns plain diesel demand through the Mini mobile tanker suppliers and transfer above ground tank from Browns plain to Marsden Depot, supply the Marsden demand using the above ground tank, Supply the current Unleaded demand of Marsden from Caltex fuel cards, and decommissioning both two underground tanks at Marsden	2267669	18403	0.8
15	Shift the current all fuels mobile tanker operation demand to Minitankers and move Shell fuel cards demand to Caltex	2193593	-55673	-2.5

This option will guarantee the supply of fuel for the Council' State of Emergency Service (SES) vehicles in case of emergency disaster. This was recognized as one of the most important user requirements for the evaluation. Similarly, alternative 12 obtained a high score in cost, bearing in mind that this alternative gives one of the smallest overruns (%0.8 per year). Similarly, a high score in Impact and benefit/cost relationship was given in this alternative because decommissioning the tanks at Marsden eliminates the risk of tank leaking that can provoke a significant environmental and expensive disaster.

C. *Sensitivity analysis*

Figure 8 examines the contribution of the assumptions in the forecast results. In other words, this analysis represents which variance in demand or price has the biggest impact on the annual total in terms of percentage. The results of the sensitivity analysis help to concentrate resources and attention in critical variables. In this case, the presented sensitivity chart shows which variability has the greatest impact in the variation of Council's fuel cost. Therefore, these variables are the most significant and require either investing resources in order to reduce those demands or change the supply to a more cost efficient alternative.

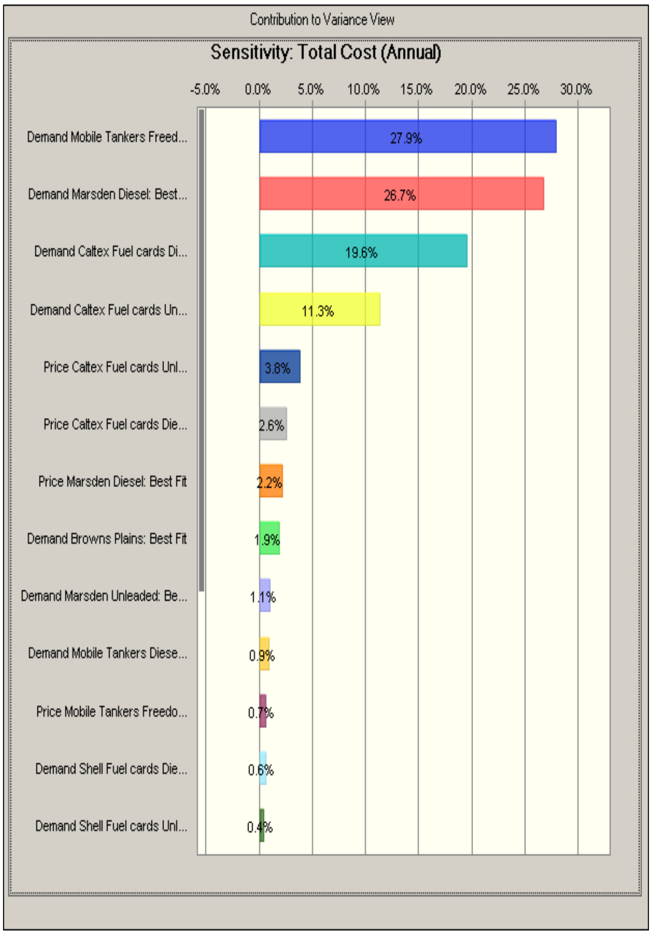


Fig.8. Trend Sensitivity analysis of total costs (Annual)

Another important tool for sensitivity analysis offered by Crystal Ball is called tornado chart, this can also be used to analyse which variables are the most significant for one specific output. While the normal sensitivity analysis computes sensibility by sampling the variables all together while the simulation is running, the tornado tool tests each variable independently of the others. Therefore, this tool does not consider correlations between variables.

Due to its seamless analysis ability and interoperability with MS-Excel platform, the cost risk simulation is facilitated. However, reliability of the potential outcomes of this simulation model depends on the reliability of the inputs algorithms. the outcomes of the simulation will be affected significantly if an error is made in the data gathering or in the simulation assumptions.

V. CONCLUSIONS

In this paper, an optimal fuel supply chain management system for large organisation's fleet operation has been developed based on important issues and considerations in cost and risk management. It reviewed the existing fuel supply chain management system of a local government organisation in Australia to evaluate the feasibility of future development alternative in fleet operation using Monte Carlo simulation. This paper illustrates important issues and considerations in cost and risk management of fuel supply operations. A quantitative model has developed to analyse the cost of different alternatives to improve the fuel chain supply. Since the trustworthiness of the data plays an important role in the prediction analysis, the input values of this analysis that come from historic series were confirmed in order to assure the consistency and validity of the results. The assumptions that are built based on historical data should be as accurate as possible to achieve a robust and reliable outcome. In future study, the inclusion of further criteria such as inflation, currency exchange in the evaluation of alternatives will provide a more balanced way for the analysis of the organisation's fuel management system.

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